Building Automation IoT Devices 2018

Abstract:

Will new technologies such as NB-IoT and LoRa create a revolutionary change in Building Automation Systems? Will IoT sensors create an avenue for integrating HVAC, Lighting, Water Management, Security, and other systems? How many Smart Home and commercial Building Automation Sensors will be used? How many IP based Security Cameras will be used in commercial and residential buildings?

April 2018

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Building Automation IoT Devices 2018

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IoT Special Report:

Building Automation IoT Devices 2018

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1 EXECUTIVE SUMMARY

Anybody that reads the wireless industry magazines has seen the stories that predict explosive growth in "Smart Buildings" which use new technologies to integrate multiple building systems together. In the utopian view, HVAC systems, lighting systems, door/window sensors, fire/smoke detectors, and many other systems would be integrated to use a common wireless protocol for quick and easy implementation.

This view ignores the fact that each of the building systems to be automated (Lighting, HVAC, etc) are highly specialized, complex systems in their own silos, and the savings of a common wireless format is tiny compared with the cost of each system.

In large commercial buildings, it's clear that automation is growing, but we see Building Automation Systems (BAS) as independent systems with thermal sensors and controls integrated with HVAC, and light sensors/motion sensors wired into the Lighting Control system. Very little integration takes places between the distinct systems because each area involves different vendors, and each vendor has proprietary methods and data formats.

In the Smart Home, these silos are not as rigid and we see some crossover of thermostats, smart appliances, security devices, and other IoT products. We document some strong growth here, although we do not see a major opportunity for high power RF hardware because the Smart Home systems are generally highly integrated low-power radios.

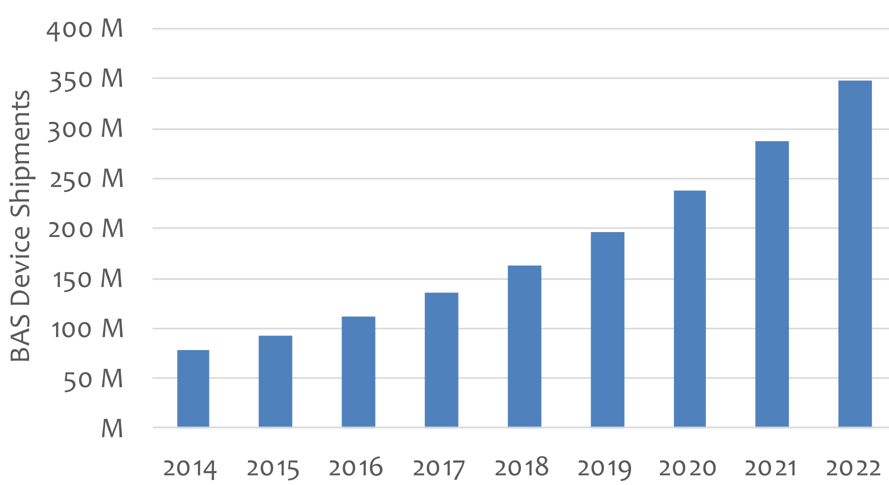

Chart 1: Total Building Automation IoT Devices, 2014-2022

Source: Mobile Experts

Overall, we see some growth in NB-IoT for Building Automation and Smart Home devices in China, where government incentives are funding start-up companies and creating platforms with ultra-low cost on mobile networks. In China, the government has two motivations: They want Chinese vendors to lead the world in NB-IoT technology, and they want the mobile operators to dominate IoT data so that the government can easily access all kinds of data.

In other countries, we do not see the same incentives and we expect that most commercial systems will remain on twisted-pair cabling. Smart home applications will make strong use of Bluetooth, Wi-Fi, and 802.15.4. LoRa and NB-IoT will be used in some sensor applications for larger buildings, and LTE will be used in some cases for video.

In the end, we do not see Building Automation as a key area of focus for companies in the RF/wireless technology areas because of heavy emphasis on wired systems and low-power unlicensed wireless at very low cost.

2 KEY APPLICATIONS

Reading media reports, people could easily get the impression that the Building Automation market is an attractive growth market for IoT devices. We have the technology to automate many different functions in a large building, including:

- Lighting;
- Air Conditioning and Heating;
- Automated Blinds or electrostatic glass;
- Security;
- Video Surveillance;
- Fire Detection;
- Energy Supply & Management;
- Water Management;
- Motion sensors; and
- Predictive Maintenance of building equipment.

Any of these individual systems can be instrumented with sensors, with information sent to a computing platform in the cloud for decisions to be made regarding building controls. This way, the facility manager can adjust the settings of a building remotely.

Each of these building systems is typically set up and controlled separately today. Some of them have been integrated with a common control system, but in the vast majority of buildings these systems are pretty separate.

Purists would say that making the HVAC system an "IoT" system means that we will be connecting every sensor to the Cloud, as an independent Internet device. In theory, each sensor could then be used by anyone for a different purpose than it was originally intended, so a sunlight sensor in your conference room could be used to augment somebody's weather forecast.

We don't take the same view. We categorize devices as IoT devices if their data is aggregated and send upstream to the cloud. That sunlight sensor is an IoT device if the data is collected together and made available on the Internet for control purposes. We fully expect the devices to be dedicated to a single purpose and to use a highly proprietary interface with some kind of gateway in the building. Many of the RF interfaces are standardized, but wired interfaces for these devices will only be standardized at a basic physical level.

We'll provide a short overview of each application for background:

LIGHTING:

To save energy, simple systems to sense motion or the presence of people in a building can be configured to control the lighting in sections of the building. The basic idea is to turn off the lights when nobody is in the room.

Another control point is to avoid lighting when sunlight makes the artificial lighting unnecessary. Sophisticated sensors can determine the range of lighting needed, and with LED lighting different levels of light can be applied to ensure the minimum energy usage at all times.

Figure 1 An office application for lighting control

Sources: MaxPixel

HEATING, VENTILATION, AND AIR CONDITIONING (HVAC):

The energy consumption in air conditioning and/or heating systems can be higher than any other single item in building operations. And at the same time, between 10% and 40% of office workers can be uncomfortable, either too hot or too cold. Independent of the IoT, the HVAC system controls in a building are challenging and have a great deal of impact.

Solutions in the industry typically involve additional sensors. Humidity sensors can help to adjust the algorithm for heating or air conditioning system control. Sunlight levels on the building can impact the system as well, so sunlight level sensors may add information to the decisions. Control of these systems is far less concerned with connecting these sensors to the Internet, and more about collecting the relevant and appropriate data, and making intelligent decisions to control every square foot of every unique building.

Artificial intelligence can play a role in these multi-variable, multi-dimensional decisions. HVAC control systems may begin to use artificial intelligence algorithms as they mature over the next 10 years, but clearly in order for this process to work the building must be massively instrumented with sensors.

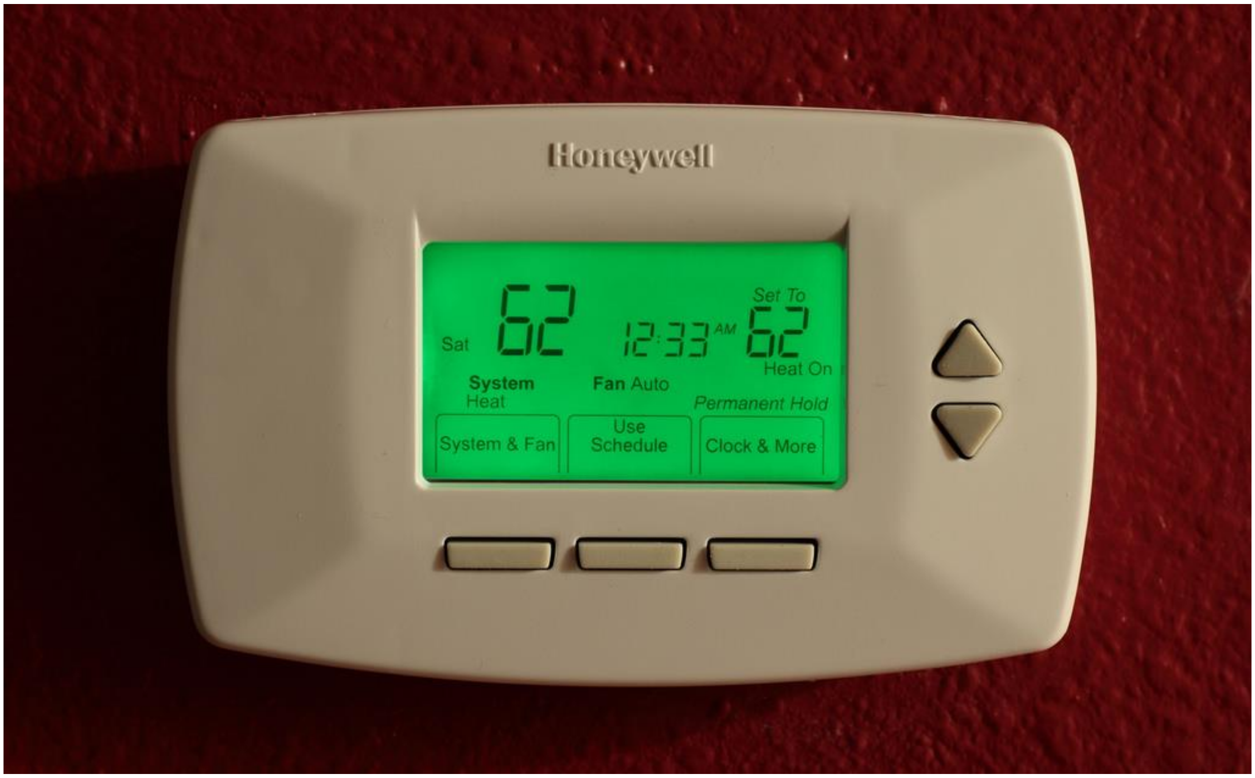

Figure 2 Typical thermostat interface

Sources: Control

AUTOMATED BLINDS, ELECTROCHROMIC GLASS:

Both lighting and thermal control of the building are related to the use of blinds or other sun shades. Depending on the architectural choices in the building, this can be extremely important in terms of saving energy.

When to close the shades or electrically block light in smartglass? That decision can involve complex decisions based on temperature and lighting conditions, so this kind of project typically involves fusion of light sensors and temperature sensors to find the optimal balance point.

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Figure 3   Example of electrochromic glass used in a hotel atrium

Sources: Control

SECURITY LOCKS ON DOORS AND WINDOWS:

Basic questions such as "which doors are locked, and which doors are unlocked" today typically require a person to walk around the building to ensure that all entry points are in the correct security state.   Newer systems make use of sensors on each door and window to relay the information to a common control point.   In many cases, actuators are also installed to lock or unlock doors as needed.

Figure 4   Example of wireless door lock

Sources: Trilogy Networx

VIDEO SURVEILLANCE:

The other half of the security question is surveillance to monitor activities near doors and other areas of the building. Clearly the video surveillance application requires much higher bandwidth for connectivity than other sensor applications, and typically video surveillance systems are set up as stand-alone systems. IP-based video cameras are starting to change the industry away from analog CCTV or other analog cameras with storage in the building. From a security point of view, it's desirable to have the surveillance storage off-site in case of fire or other risk to the storage medium itself.

A typical deployment with high-resolution cameras can create about 2 TB per month per camera, so this application is very focused on data transport at low cost.

Figure 5   Network camera based video surveillance

Sources: Netgear

FIRE DETECTION:

Temperature sensors used in the HVAC system could theoretically be used to detect fire as well, and smoke detectors are a common sensor to be applied as a check. Other sensors can include the good old-fashioned pull handles, gas detection, waterflow monitors, and even flame detectors (light meters tuned to a specific light wavelength).

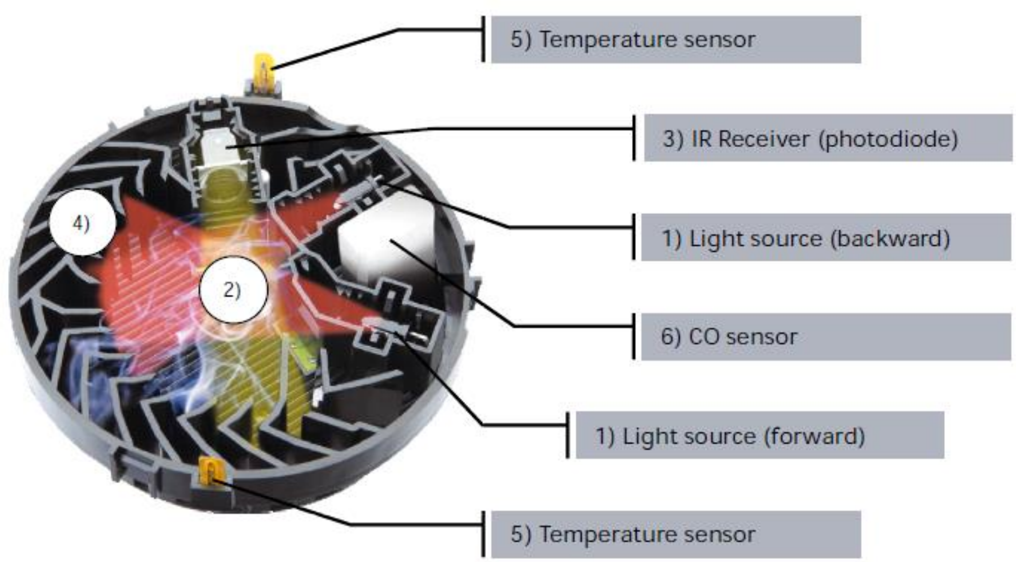

Figure 6   Advanced fire/smoke/CO/temperature sensor

Sources: Siemens

ENERGY SUPPLY AND DEMAND MANAGEMENT:

Large-building facility managers often can negotiate cheaper prices for energy if they agree with the local utilities on energy usage during peak times. The utility can issue a Demand Response message, and the building's systems can be automated to respond by turning down lighting, HVAC, or other systems. The ACEEE found that energy savings can be as much as 27%, with an average of about 10% in terms of kW of power. The dollar savings passed on to the customer can be in the range of about 20% as well. The business model is simple: if a utility can avoid building more peak energy capacity through demand management, then they pass at least half of the savings on to the customers that use power.

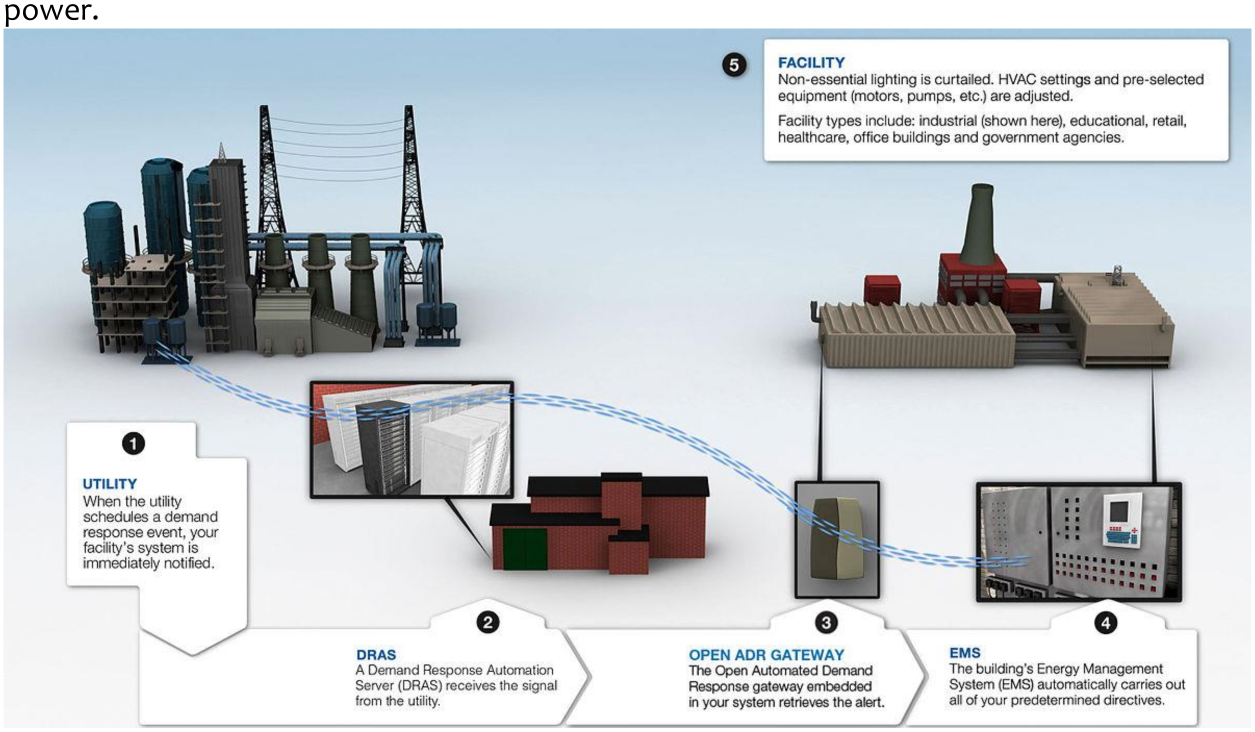

Figure 7 Energy Management System application using Demand Response Automation

Sources: Honeywell

WATER MANAGEMENT:

Tall buildings have water systems that are much more complex than people realize. Pumps, chillers, boilers, solar heaters, cooling towers, wastewater management, irrigation systems and leak detection systems are all involved.

Innovative building water systems collect condensation, filter and soften the water, and integrate water systems with building heating and cooling systems.   Individual examples of almost every conceivable type of integration have been implemented for unique buildings around the world.

With regard to sensors, this means that sub-metering sensors can detect leaks, temperature sensors can control heaters and chillers, and weather sensors can adjust irrigation.   Control systems for water usage are generally independent of heating/cooling systems, but some vendors are considering closer integration of the water heater/cooling systems, driving customized control systems.   There is no standard solution here—it's a very customized market for control systems, sensors, and actuators.

Figure 8   The Agora Garden Tower in Taipei with rain catchment irrigation

Sources: CTBUH

MOTION SENSORS –DETECTING PEOPLE:

Motion sensors are often used to control the lighting system, and control of the lights can be done with centralized building infrastructure—but lack of sensors throughout the building can be a barrier to implementation. Wireless devices can be a quick solution to implement motion sensors for energy savings.

Other applications can include monitoring the number of people in retail or transportation-related buildings, to direct services in order to maximize retail revenue.

Predictive Maintenance:

As in many other vertical markets, IoT devices can report data on machines that start behaving erratically. If an air-conditioning compressor or a water pump starts to vibrate, it is likely to fail in the near future.   Predictive maintenance is intended to make a change before building operations are disrupted, or before serious damage is done to a building system.

3 MARKET DRIVERS AND CHALLENGES

The market for instrumenting a building with IoT devices is driven by environmental ratings and by operating costs. So far, we have not seen significant applications that enable something that cannot be done with existing systems… so using the "IoT" in building automation is limited in value, simply making building controls more accessible via cloud platforms.

ENVIRONMENTAL RATINGS:

LEED rating is pretty well known, as a system created by the US Green Building Council representing adherence to standards of "Leadership in Energy and Environmental Design". Four levels of certification are possible, based on the number of points accumulated out of 100 points possible, according to design criteria:

LEED Certified: 40 points
LEED Silver: 50 points
LEED Gold: 60 points
LEED Platinum: 80 points

Points are awarded on criteria related to seven "impact categories and weighted to calculate a total score.

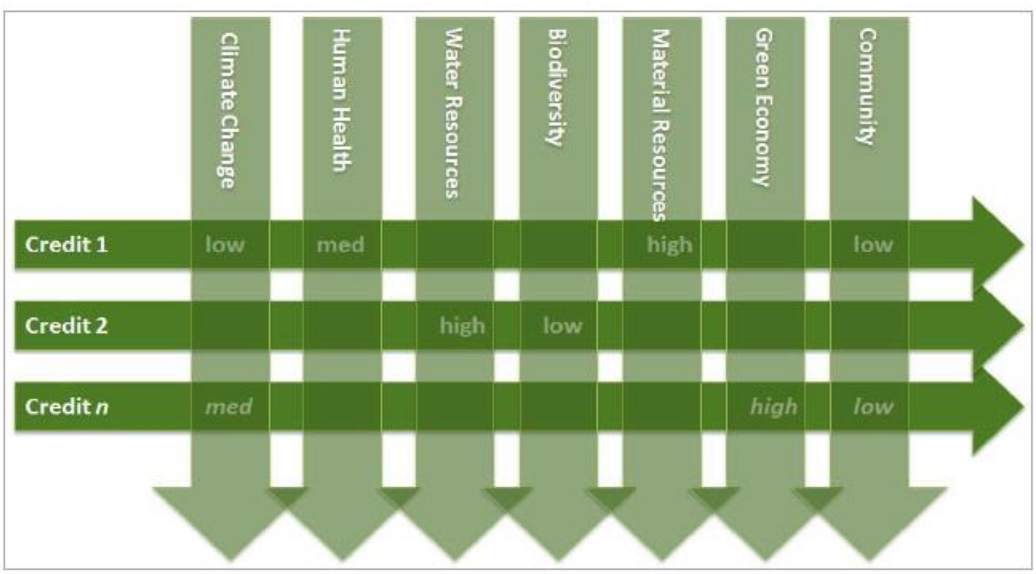

Figure 9 LEED certification factors

Sources: USGBC

Using this approach, the LEED Steering Committee hopes to reverse human contribution to global climate change, enhance human health, protect water, biodiversity and material resources. The bottom line: In order to achieve a high LEED rating, building must increasingly focus on energy efficiency, storing or using rainwater, and smart water usage.

In addition to the well-known LEED system, there are multiple other building rating/certification options:

- Energy Star provides a government certification using energy and water efficiency benchmarks.
- Green Globes is cited in some government mandates in the USA and Canada, and uses energy, site, water, emissions, and a few other categories for a multi-variable rating.
- Living Building Challenge (LBC) requires 100% net zero energy, 100% net zero water, on-site renewable energy, and 100% recycling. This difficult standard is not often required by governments due to its ambitious goals.
- NZEB: The Net Zero Energy Building certification is offered by the International Living Future Institute (ILFI). The main criterion is simply to have 100% of energy needs supplied by on-site renewable energy.
- Passive House Insititute US (PHIUS) was developed under the US government's Department of Energy to tailor architecture to local climate conditions for improved efficiency.
- Green Business Certification Inc (GBCI) offers a certification for Sustainable Sites Initiative (SITES) which focuses on landscape architecture and streetscapes.
- Green Mark was developed by the Building and Construction Authority in Singapore to rate buildings according to energy and water efficiency, as well as environmental impact. The program in Singapore offers cash incentives to developers to reach specified goals.
- BEAM is a voluntary program in Hong Kong, with a multi-variable rating system to increase awareness.
- BREEAM (Building Research Establishment Environmental Assessment Method) was the first building rating system and has been used since 1990 in Europe and the Middle East. BREEAM ratings are required for many government buildings in these regions. The BREEAM system rates buildings on energy, waste, pollution, materials, and other factors.
- CASBEE: (Comprehensive Assessment System for Built Environment Efficiency) is a Japanese initiative for green buildings. CASBEE covers energy efficiency, resource efficiency, local environment, and indoor environment.
- EDGE (Excellence in Design for Greater Efficiencies) is a certification system for new construction for emerging markets. Sponsored by the World Bank, this is one attempt to push green techniques into emerging markets.
- Pearl Rating System for Estidama: This initiative in Abu Dhabi is a rating system based on environmental, cultural, social, and economic factors.

Some of these initiatives are voluntary, or have simple criteria. They become essential when a local government chooses to impose a requirement for certification for a building project. In most of these cases, certification can be achieved without the use of IoT connectivity, because building systems can be operated independently. However, to reach the higher ratings (such as LEED Platinum), tight control over environmental systems can be best achieved using automation with sensors throughout the building.

COST SAVINGS:

Independent of using building automation to satisfy a requirement for certification, there are cost savings available to the facility manager that uses tightly controlled systems. The biggest impact comes from HVAC and lighting savings.

In one example, an average warehouse uses 6.1 kWh of electricity per square foot annually for lighting and air conditioning. At an average of $0.13 per kWh, that's about $800K annually to light a million-square-foot building. That's enough to justify installation of a motion sensor-based system to sense worker activity and turn on lights as needed. Of course, every system is different but in this simple example it's easy to imagine savings of $300K or more per year after investing $100K in a system of motion sensors and light control.

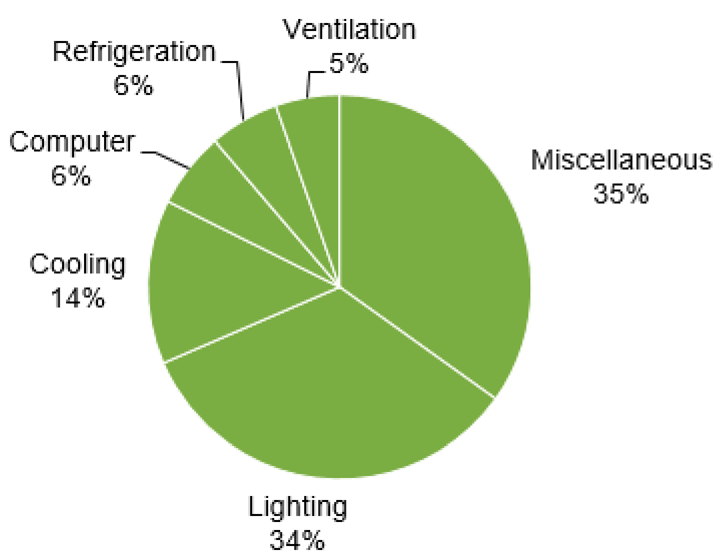

Figure 10 Electricity use in an average American warehouse

Sources: US EIA

Market Challenge--interoperability:

Despite motivation for improved automation in buildings, the structure of the industry doesn't make anything easy. Lighting, HVAC, water management, and security systems are almost always built by different companies (and sometimes multiple suppliers in the same area). This means that in general the automation of these systems happens in silos. The lighting system can be upgraded, and possibly will use motion sensors or other sensors, but will not be integrated with the automated shades unless a firm is brought in to develop some customized control systems.

The silos are a major barrier to the growth of this market. Despite the success of LEED certification in driving awareness and automation, we have seen little movement in cross-connections between systems, or movement to make sensor data available between different systems.

As a result, we do not anticipate the "multiplier effect" that is possible when various IoT devices create a pool of data for several common applications. Each building system will have its own sensors, connected on separate interfaces. The impetus for a common connectivity strategy is weak because of the lack of coordination between systems.

In this way, we don't consider IoT devices in Building Automation to fit the purists' description of IoT devices. (where the IoT sensor data is available on a Cloud platform for multiple applications to use). Instead, we see sensors connected via wires and via captive wireless links for each independent silo.

Market Challenge—Legacy Wired Connectivity:

Companies that supply control systems for lighting, HVAC, and other systems have developed wired interfaces for many years—in some cases these companies have been using the same analog wired interfaces for more than fifty years. The inertia related to changing these interfaces is real. The companies do not have RF engineers on staff and spend very little R&D attention on the interfaces themselves, since they are concerned with improving the control loop itself and the user interfaces. These companies have moved recently to put information and control panels on a cloud interface, but in general this means that an in-building system collects data, controls the system locally, and has a single interface point on a web portal.

The benefits of moving to a new wired interface (such as Ethernet) or a wireless interface (such as LoRa or NB-IoT) can come into play for new building construction, where the cost of physical wiring can be reduced. However, in most existing buildings the "path of least resistance" involves simply using the existing sensors and wires.

4 Connectivity Technology Options

The connectivity for Building Automation systems can include a variety of choices:

1. Ethernet;
2. ARCNET;
3. LonTalk;
4. Bluetooth;
5. Zigbee and other 802.15.4 formats;
6. Wi-Fi;
7. GSM, 3G, and LTE; and
8. NB-IoT.

Ethernet

Ethernet is a communications protocol that takes multiple physical forms, including twisted-pair cabling, fiberoptics, and point-to-point microwave links, among others. In the context of Building Automation systems, Ethernet generally refers to twisted-pair cable such as Cat-5 or Cat-6a cable for low voltage communications through the building.

ARCNET

Attached Resource Computer Network (ARCNET) is a local area networking protocol originally developed in the 1970s, and commonly used in older embedded systems. ARCNET has been standardized as ANSI ARCNET 878.1. Years ago, ARCNET had cost advantages and some technical advantages in terms of longer cable runs than Ethernet. However, as Ethernet has scaled up to millions of networks, the cost of Ethernet switches and other devices has become very low and today Ethernet components enjoy lower cost and higher availability.

LonWorks

Echelon Corporation developed LonTalk as a control communications protocol in the 1990s, and standardized by ANSI as ANSI/CEO-709.1-B. Later this standard was adopted as EN 14908 for European building automation, and China also adopted a variation in the mid-

2000s. LonTalk/LonWorks has also been listed as an optional data link/physical layer for BACnet.   In 2008 LonTalk/LonWorks was further standardized as ISO/IEC 14908.

LonTalk/LonWorks uses twisted pair connectivity as well as power line carrier connectivity. The twisted-pair format uses two wires at 78 kbps using differential Manchester encoding. The power-line communications protocol can reach about 5 kbps

BLUETOOTH

Bluetooth is commonly used for local communications with systems by a technician, replacing the old RS232 or RS485 cable with a simpler wireless connection. HVAC systems or lighting systems that are mounted high on a ceiling are good applications for local control via Bluetooth.   Bluetooth (1.0 through 5.0) variations are all configured for basic security, operate over a limited range, and allow for reasonably high data throughput with low power consumption.

BLE adapts the old Bluetooth standard by limiting the time to send data to 3 milliseconds, compared to 100 milliseconds for Blutooth "classic".   In addition, BLE uses a slow acknowledgement approach to save on power.   The net impact is that power consumption can be 50% to 90% reduced, compared to a Bluetooth 2.0 baseline.

BLE uses 128-bit AES encryption, so it is generally considered secure enough for building systems.

	BLE	**Zigbee**
Frequency	2.4 GHz	2.4 GHz
Modulation	GFSK	OQPSK
Channel Bandwidth	2 MHz	2 MHz
Configurations	P2P, star	P2P, mesh
Data Rate	1 Mbps	250 kbps
Security	128 AES	128 AES

Figure 11   Technology Comparison: BLE and Zigbee

Source: Mobile Experts

EnOcean

EnOcean is a wireless technology for ultra-low power sensors that transmit infrequently. The EnOcean concept involves energy harvesting (from a button push, from motion, from a temperature delta, or from light), but it should be understood that the wireless connectivity is separate from the various forms of energy harvesting. The wireless transmission works at 868-928 MHz in the unlicensed ISM bands, with very low power over a range of 30 meters or less. This makes EnOcean useful in some smart-home applications but not ideal for large buildings.

One concern that we have is the low power use case in unlicensed bands. What happens when a wireless microphone or other device is used in the same building? Interference immunity is not proven with EnOcean so we are skeptical.

Having said that, we note that EnOcean has a long list of case studies in which they describe applications of installed EnOcean devices in office buildings, shopping malls, universities, churches, and other buildings. The battery-less aspect of the technology may create some appeal.

Figure 12 EnOcean concept in building automation

Source: EnOcean

802.15.4 ZIGBEE AND 802.15.4J

ZIgbee technology is used for some products such as locks, door/window sensors, and other security products that are generally designed for residential use. Zigbee's range is often too short for operation in larger buildings, with an effective range in a large concrete building in the range of only 20-50 meters.

Zigbee devices can work via mesh topology, extending range in some cases to several hundred meters or even farther. Of course, this topology relies on the presence of Zigbee nodes every 20 meters or so in order to overcome obstacles such as concrete walls or metalized glass. In addition, one tradeoff of mesh networking is that battery life for meshed devices drops dramatically.

The Zigbee stack allows for very low power operation, and open reference designs from multiple companies makes a good environment for developers that want to tweak the Zigbee protocol in some way to suit their application.

The basic modulation format is offset-quadrature phase shift key, which allows asynchronous operation from multiple devices and maintains a low peak-to-average ratio for efficient amplifier operation. Zigbee can reach about 250 kbps in a 2 MHz channel.

WI-FI

Wi-Fi is attractive because it's widely available in many buidings, but as an IoT connectivity standard Wi-Fi has problems with battery life and range of operation.

Wi-Fi is standardized by IEEE under 802.11, with releases now up to 802.11ac, 802.11ax, 802.11ay, among others with options from megabits per second up to gigabits per second. Unlicensed frequency bands are used at 2.4 and 5 GHz for relatively short-range communications. The Wi-Fi protocol has been popular for smart-home applications due to its ubiquitous coverage of homes, so products such as Nest thermostats and Roomba vacuum cleaners connect via Wi-Fi.

Wi-Fi is utilized in smart home systems but less often applied in larger commercial buildings. Looking at lighting controls, thermostats, and security systems for commercial applications, we do not see Wi-Fi listed as a connectivity option in most cases.

LoRa:

LoRa (referring to the Long Range wireless protocol promoted by the LoRa Alliance) offers long-range connectivity with low cost and long battery life, and the open ecosystem of LoRa allows for operation in an ad hoc system without the intervention of a telecom operator. In this way, LoRa compares favorably with NB-IoT because it has similar characteristics but it works under a business model which is more compatible with building automation systems.

Figure 13 An example of a wireless door/window sensor

Source: Netvox

GSM, 3G, LTE, LTE-M:

These technologies use licensed frequencies ranging from 700 MHz to 2.6 GHz, generally with high power transmitters (up to 3W, or 250 mW for small devices). 3G and LTE standards are tailored for high data throughput, from 300 kbps up to 30 Mbps, but GSM technology is more suited to about 5-10 kbps with wide coverage in all locations.

Because of high power consumption, these radios are generally only used as a "backhaul" link for a gateway, not for sensors themselves that rely on long battery life.

LTE Category M changes the picture, as the latest release of LTE provides up to 1 Mbps of data over long range (3 miles or more) with low power consumption, opening up the possibility of connectivity in remote areas, or in buildings with enough bandwidth to handle voice connectivity.   Elevators could be one possible application for LTE-M technology, as the wireless link could provide enough bandwidth for voice connectivity in an emergency.

Security camera, intercom, and other high-bandwidth, long range applications can also make use of LTE-M. In a standard implementation, the data would flow to the local cellular tower, through the mobile operator's core network, and back into a cloud application.   New business models are likely to emerge soon in which unlicensed bands can be used for LTE-M, allowing a building system to use this format locally.

Figure 14   An example of a wireless gateway for LTE Cat-4, Cat-M, and Cat-NB1 devices

Source: Sierra Wireless

NB-IoT:

LTE Category NB-1 (commonly called NB-IoT) is a narrowband variation of LTE communications with reduced bandwidth and greatly reduced power consumption.   The range of NB-IoT connectivity can be as much as several miles, so this format has a good compromise of long battery life, long range, and low cost.

Early use of NB-IoT in China has moved quickly in building automation systems such as water sub-metering, lighting control, elevator control, and HVAC sensors.   Deployment in the field is still in its infancy but at least in the Chinese market the development activity for building automation products based on NB-IoT is well underway.

BACNET:

BACnet is a protocol developed to make multiple building systems interoperable. The BACnet protocol is independent of the transport mechanism, so any wireless format could be used to transport data for BACnet. Having said that, it's clear that almost all of BACnet deployments so far have used Ethernet, ARCNET, or MS/TP (master-slave/token-passing) protocols with twisted-wire cabling to date.

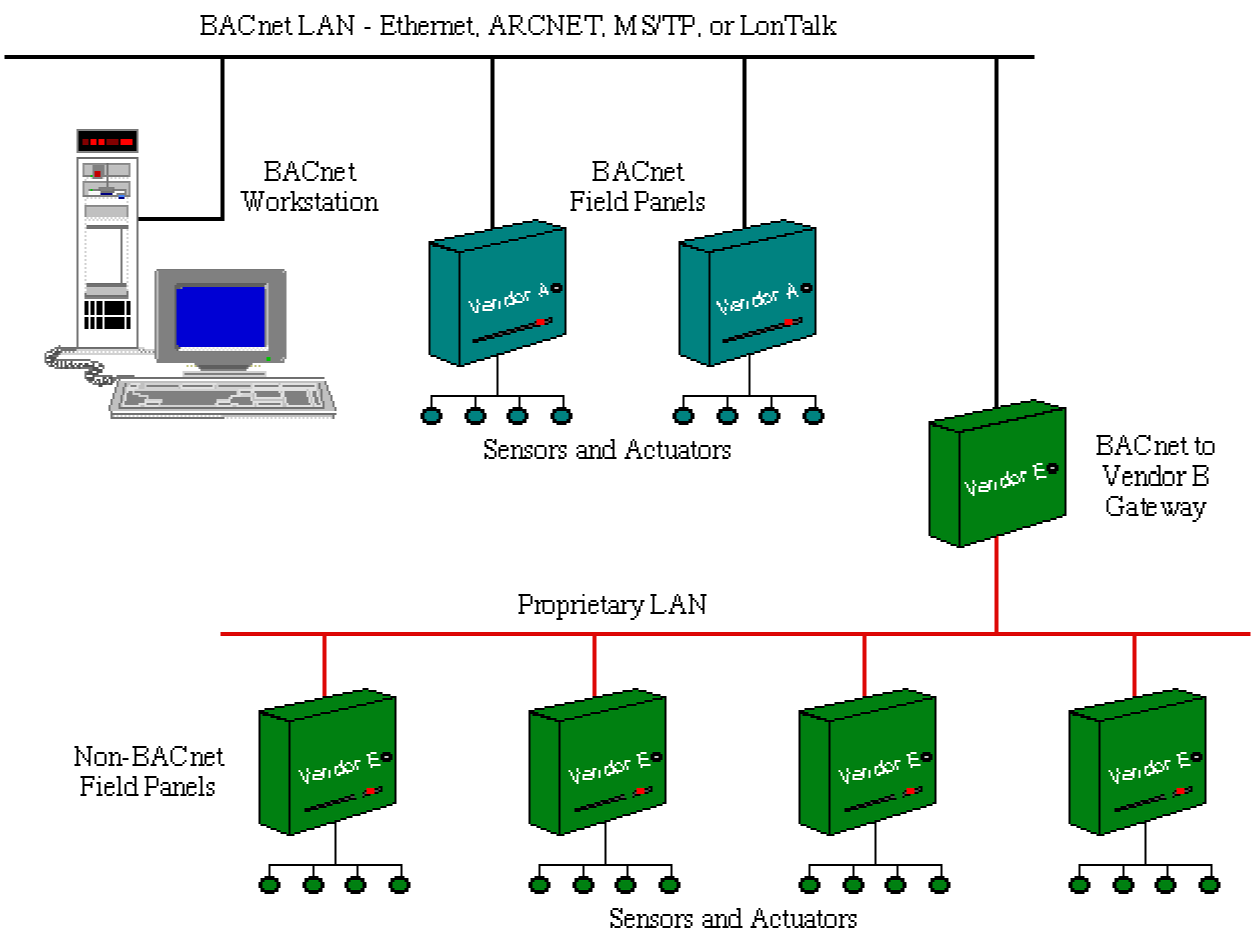

Figure 15 Architecture diagram for BACnet

Source: BACnet.org

5 OUTLOOK FOR BUILDING AUTOMATION DEVICES

Our overall view of the Building Automation market is that the market is already fairly mature in terms of using sensors (thermostats, motion sensors, etc). Heck, HVAC systems have been using sensors for 50 years. The recent trend for modernizing the building automation control system is related to certification requirements for LEED and other building standards.

As the environmental standards for buildings get tighter, we expect slowly growing pressure to make HVAC, lighting, water management, and other systems more sophisticated. This means that more sensors will be used and a greater variety of control points will be used.

We DO NOT expect that the Building Automation market will converge into an interoperable system that uses sensors between different systems. For example, daylight sensors used to control lighting are not likely to be used in HVAC control. We expect these systems to remain separate.

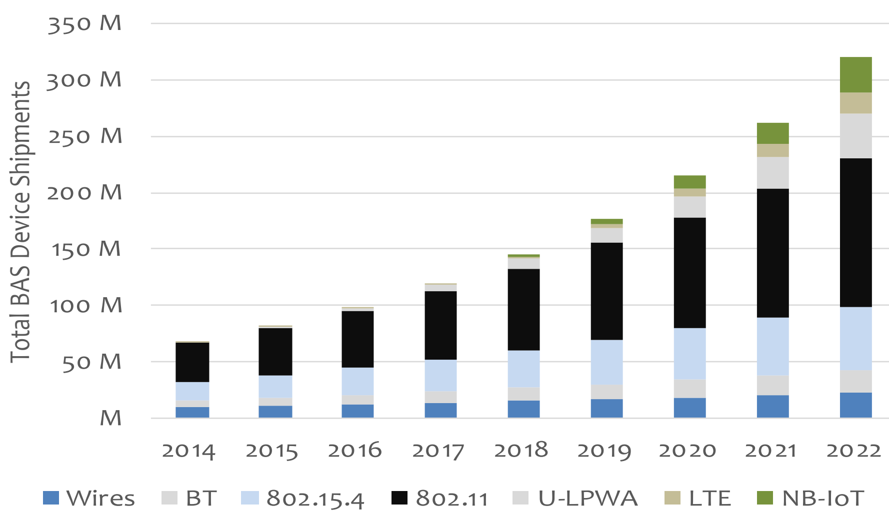

Chart 2: Overall Building Automation Device shipments, by connectivity, 2014-2022

Source: Mobile Experts

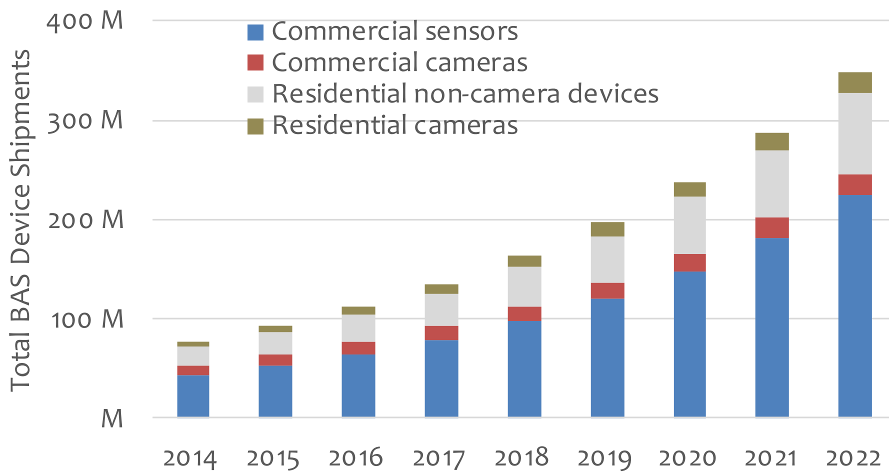

Chart 3: Overall Building Automation Device shipments, by application, 2014-2022

Source: Mobile Experts

COMMERCIAL BUILDING AUTOMATION DEVICES

One of the main focus areas of this report was to examine the need for higher power, wide area RF connectivity for large commercial buildings to adopt new security cameras, thermostats, lighting control, and other features. Will new technologies like NB-IoT and LoRa dramatically change the adoption curve? We think that the answer is generally no. There is ongoing growth in adoption of automation in HVAC, lighting, and other systems, but it's not "driven" by new technology. It's driven by a desire for environmental certification, and wires will continue to be used in many cases. In the end, we don't see a strong shift away from Ethernet/BACnet/LonWorks on twisted pair cabling despite the possibility of multiple wireless techniques. The exceptions are in China, where NB-IoT technology is strongly favored by the central government and strong incentives are applied at all levels of the economy to involve the carriers in everything from elevator controls to security locks.

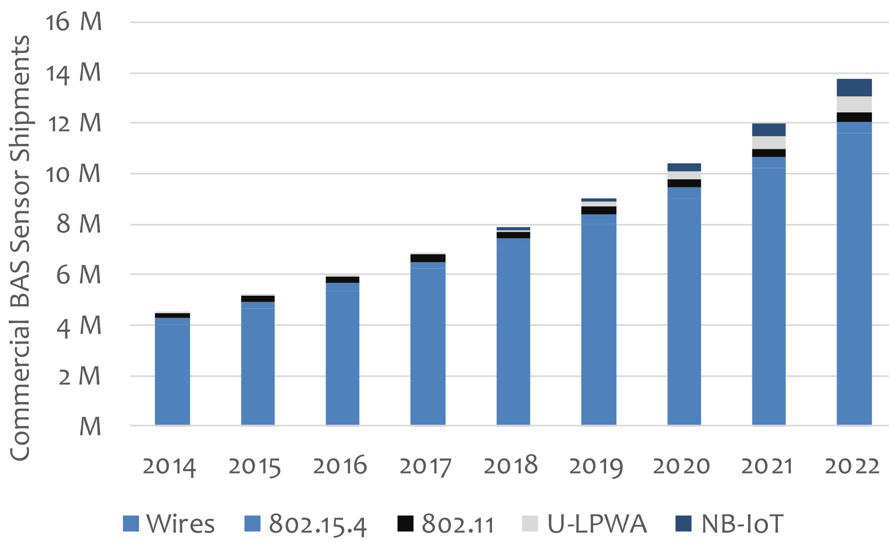

Chart 4: Commercial Building Automation Device shipments, 2014-2022

Source: Mobile Experts

COMMERCIAL SECURITY CAMERAS

We break out security cameras as the single application that is different than thermostats/lighting controls/water sub-meters and others, because the bandwidth requirement for a security camera is very different. In addition, while other BAS systems can be locally controlled, some building owners want security video content to be stored offsite in case of a major emergency.

We see a growing market, especially in China, for LTE-based security cameras. However, most of the worldwide growth will remain on 802.11 or on twisted pair cabling.

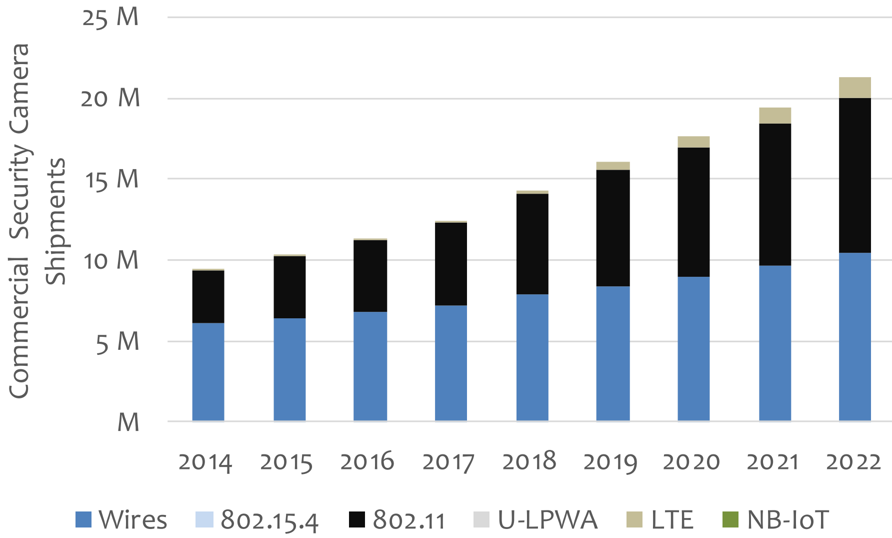

Chart 5: Commercial Security Camera shipments, 2014-2022

Source: Mobile Experts

Smart Home Devices

The focus area for this report was on commercial building automation, but we looked at the smart-home device trends as a guide to understanding the economy of scale and the possibility of residential devices crossing into the enterprise markets. In general we still see fragmentation in the smart-home space. There is strong shipment growth but we don't see any platforms rising to the surface that would cross over to the commercial markets at this time.

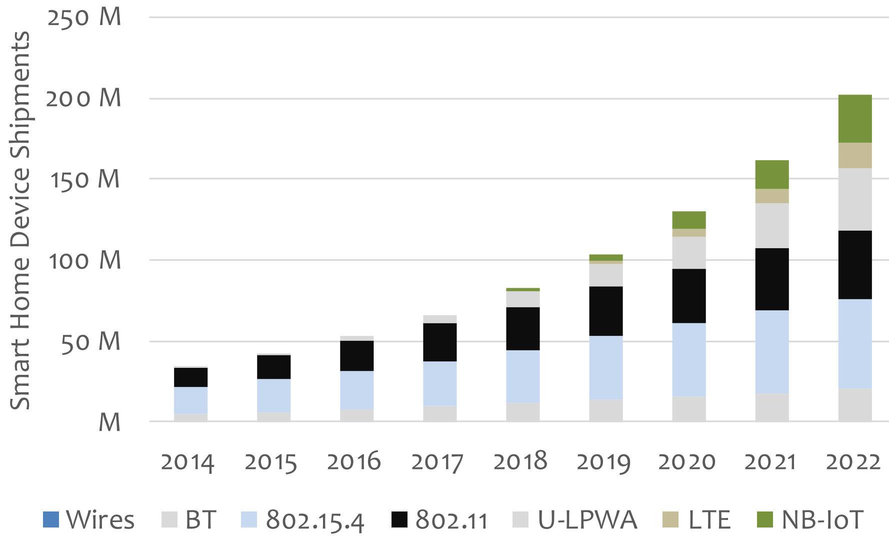

Chart 6: Smart Home Device shipments, excluding cameras, 2014-2022

Source: Mobile Experts

RESIDENTIAL CAMERAS

IP-based security cameras have become popular quickly in the residential markets and are also starting to take over the analog closed-circuit video market for commercial buildings. In the residential space, 802.11 based cameras are very quick and easy to install. As LTE gets cheaper, especially in China we expect to see a few products using LTE instead of 802.11.

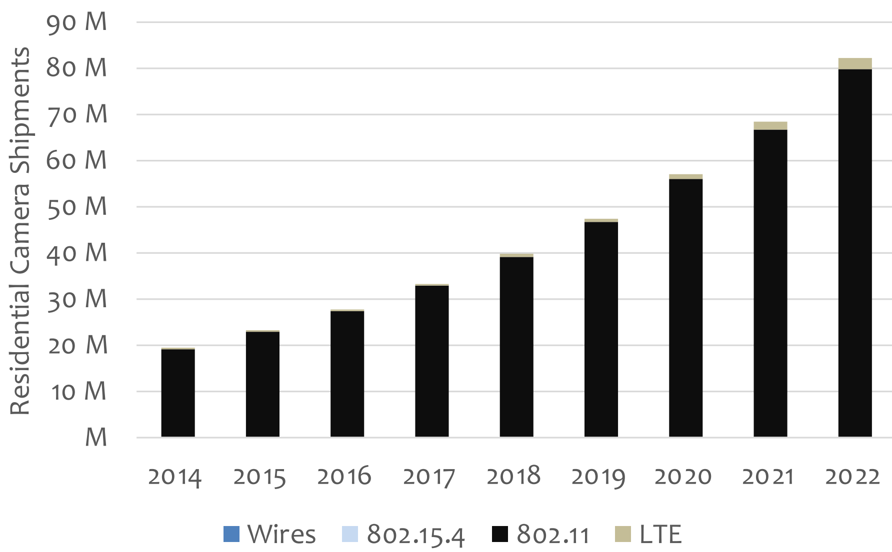

Chart 7: Residential IP-based cameras, 2014-2022

Source: Mobile Experts